Two-Band Superconductivity in Pure and Doped MgB_2

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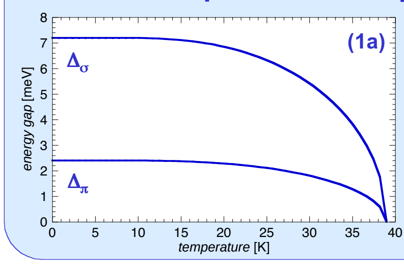
Objective

The compound MgB_2 is an elegant example of a two-band superconductor where super-conductivity is mediated by the electron-phonon interaction between the 2D σ-bands and a B bond-stretching phonon mode, and induced into the 3D π-bands primarily by interband electron-phonon coupling. In the absence of strong interband scattering, each band displays a different energy gap (see Figs. 1a and 2a). However, with very strong interband scattering the distinct superconductivity in these bands is predicted to homogenize, such that the gaps merge to an intermediate value and the critical temperature, T_c, decreases (see Fig. 1b). We used point-contact spectroscopy to study the tunneling density-of-states and search for spectral features related to interband scattering.

Result

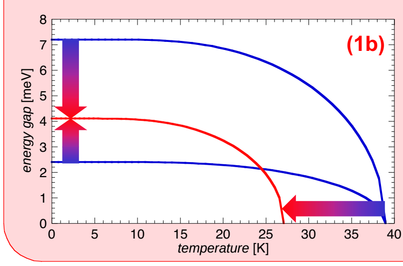
Our experiments on undoped MgB_2 have identified interband scattering in the electron self-energy through dips in the tunneling density-of-states (see Fig. 2b), but the scattering is too weak to merge the gaps. To test for this merging of the gaps, we have introduced considerably more scattering by substituting ~10% of the B sites with C, which also reduces T_c from 39 to 22 K. However, our point-contact tunneling on these samples still does not show a merging of the gaps to an intermediate value, but rather that the small gap decreases in proportion with the T_c reduction, i.e., from 2.5 meV to 1.5 meV (compare Figs. 2b and 2c). Thus we conclude that this C-doping level does not significantly increase *interband* scattering in spite of the strong evidence for a large increase in *intraband* scattering. To reconcile this we conclude that there must be a selective suppression of interband *impurity* scattering (see Fig. 1c), and such a possibility has been suggested by Mazin *et al.*, who attribute it to the disparity between σ- and π-wave functions.

Two Band Superconductivity (clean limit)



Two gaps observed by many groups
e.g., our data and fit, Physica C 385, 221 (2003)

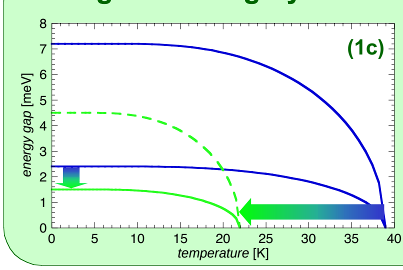
Effects of Interband Scattering



***Weak* interband scattering affects self energy**
dips at ~11 meV measured by us, PRL 88, 127002 (2002)

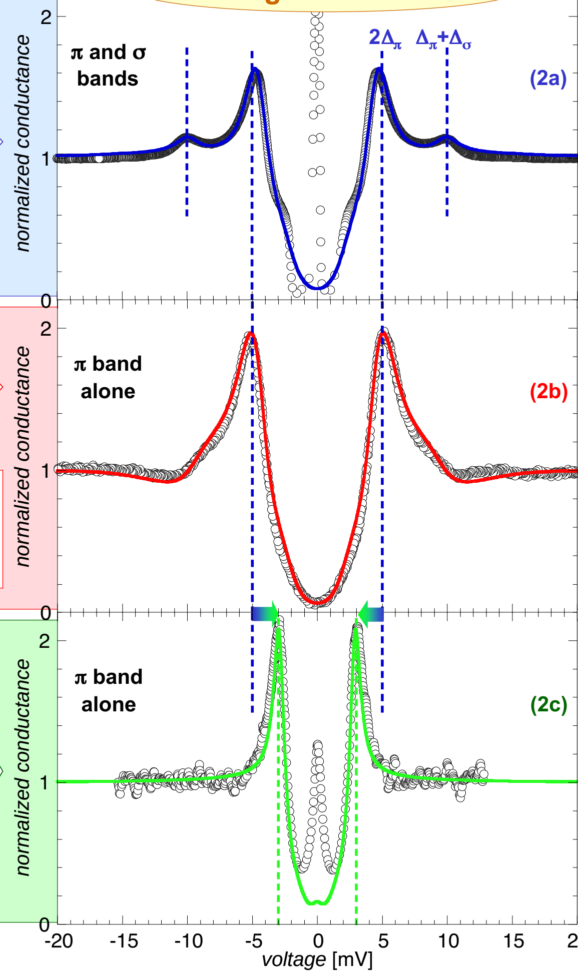
***Strong* interband scattering homogenizes the gaps**
predicted by Liu et al., PRL 87, 087005 (2001)

Strong Scattering by 10% C Doping



Selective suppression of interband *impurity* scattering
predicted by Mazin *et al.*, PRL 89, 107002 (2002)
lower T_c and gap seen experimentally by us, PRB 68, 0605XX (2003)

Argonne Data



Future Direction

H. Schmidt et al.,
"Retention of Two-Band Superconductivity in Highly Carbon-Doped MgB_2"
Physical Review B 68, 0605XX(R) (2003)

This surprising conclusion was enabled by our break-junction tunneling technique that readily achieves superconductor-insulator-superconductor (SIS) junctions, which exhibit greatly enhanced spectral features. We plan to create SIS tunnel junctions using single-crystalline samples of known orientation, with the aim of understanding the coupling between the 2D and the 3D band in high magnetic fields, where the 3D coherence peaks are strongly suppressed.

BES - DOE

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